Remote Detection Coil Setup for Imaging High Velocity Flow Dynamics of Gases with Hyperpolarized 3Helium

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Introduction

High-frequency oscillatory ventilation (HFOV) is a ventilation technique used in patients with acute respiratory distress syndrome (ARDS). Compared to conventional ventilation, the tidal volume of HFOV is reduced in order to minimize lung injuries. In return respiratory frequency is increased to maintain ventilatory gas transport of O_2 and CO_2. Using hyperpolarized ^{3}He or thermally polarized fluorinated gases MRI can contribute to the understanding of the complex gas transport mechanisms in HFOV [1-3]. To optimize this technique a deeper understanding of the gas flow dynamics has to be conceived. One approach is the usage of phase contrast imaging. High flow velocities up to 40 m/sec and the small dimensions of the airways are a big challenge in this context. To achieve high spatial resolution on a trachea phantom a remote detection coil setup using an eight rung birdcage resonator for excitation of rapidly moving spins and two separate receive elements for placement downstream has been designed and tested.

Methods

Transmit coil: The transmit coil is an eight rung birdcage tuned and matched to 48.51MHz for imaging hyperpolarised ^{3}He. To compensate asymmetries in the two resonant modes two extra endrings which were connected to the first by a trim capacitor. **Receive elements:** The receive elements were realized with three turn spiral loops tuned to 48.51MHz. To achieve a sufficient decoupling between the elements the coils were decoupled by active preampdecoupling [4] which is known from phased arrays. Because elements will be separated over several cm this was considered to be sufficient.

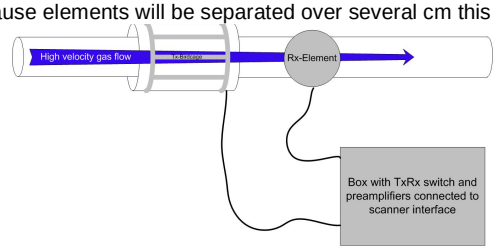

Fig.1: Principle setup for showing the feasibility of the remote detection coil setup.

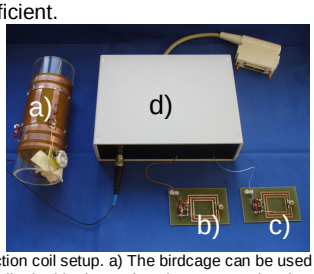

Fig 2: Remote Detection coil setup. a) The birdcage can be used as a transmit only or transmit/ receive coil. The b)+c) Receive elements can be placed on the simulated trachea or on a possible bifurcation to achieve optimum SNR even at high velocity gas flows. d) Interfaceboard to connect the coils to the scanner.

MRI experiment: To prove the feasibility of this concept a long acrylic tube (16mm inner diameter) was used to simulate the trachea (Fig. 1). A mixture of 1200 ml N_2 and 200 ml hyperpolarized ^{3}He was applied with high speed in the tube system while a MRI phase contrast sequence (TR/TE=10/4ms, Voxelsize= 0.3x0.6mm^2) was started.

Results

The coil parameters were carefully adjusted and the setup was tested. Using the birdcage coil for Tx/Rx (Fig.3) already showed a very good SNR performance. Considering the worse conditions for using distant placed Rx-1 element (Fig.4) SNR could be increased with the rx-elements to observe high speed velocity profiles.

Coil	*$Q_{unloaded}$*	*Preamp decoupling [dB]*	*Active detuning [dB]*
Tx-Birdcage	225	-	30.7
Rx-1	133	29	39.5
Rx-2	144	22	33.5

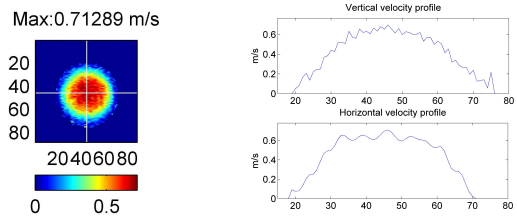

Fig.3: Phase contrast data and velocity profiles acquired by using the Birdcage coil as a transmit/ receive coil what is possible for low and moderate flows.

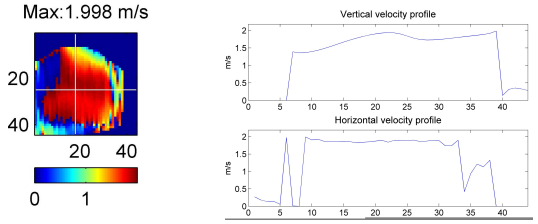

Fig.4: Phase contrast data and velocity profiles acquired by using Rx-1. Because of the higher velocity in the short tube no laminar profile can be observed. But even a few cm behind the transmit coil, velocity data can be acquired.

Discussion

For studying flow dynamics with HFOV MRI sequences have to be optimised for this new coil setup. Also precise triggering between the HFOV-ventilator and the scanner has to be implemented for achieving exact information about the gas dynamics. Nevertheless the first results show the feasibility of the presented setup and the big potential to understand principle questions of HFOV. With normal used single channel volume coils which cover the full length of the tube this high resolution data was impossible to acquire. Since the new coil setup is ready sequence parameters have to be optimized.

Reference

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